MECHANICAL PROPERTIES OF SOFT CLAY STABILIZED WITH CEMENT-RICE HUSKS (RH)

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To my beloved mother and family…..

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ABSTRACT

Chemical stabilization has been extensively used for the improvement of soft clay soils, in enhancing the shear strength and limiting the deformation behaviours. Cement is widely used as a stabilizing material for soils, but the increasing price is causing economic concerns among practitioners and clients alike. The quest for alternative cheaper stabilizing agents is therefore more urgent than before. Rice husk is a major agricultural waste in Malaysia and the common disposal method of open burning has notoriously contributed to environmental pollution. The possibility of admixing rice husks with cement for stabilizing soft soils could be a solution to both problems. This study was aimed at assessing the usefulness of cement-rice husks as an effective soil stabilizer for improving the mechanical properties of clay soils. Laboratory experiments were carried out on a stabilized soft clay to study the inter-relationships between shear wave velocity, one-dimensional compressibility and unconfined compressive strength. Bulk clay samples were collected from the Research Centre for Soft Soils (RECESS) of UTHM. The stabilized specimens were prepared with the clay admixed with 5 % and 10 % cement and various quantities of rice husks, then compacted into cylindrical specimens measuring 38 mm in diameter and 76 mm high. The specimens were then left to cure for different periods up to a month. The stabilized specimens were observed to undergo increase in stiffness and strength, as well as significant reduction in compressibility, highlighting the great potential of cement-rice husk as an alternative soft soil stabilizer.

Keywords: Clay soil stabilization, cement, rice husk, shear wave velocity, one-dimensional compressibility, unconfined compressive strength

ABSTRAK

Penstabilan secara kimia telah digunakan secara meluas dalam penstabilan tanah, untuk menaikkan nilai kekuatan ricih tanah dan menghadkan ciri-ciri pemendapan tanah. Simen telah lama digunakan sebagai bahan penstabil tanah, tetapi kenaikan harganya merisaukan ekonomi pengguna yang terbabit. Oleh itu, permintaan terhadap agen penstabil yang lebih murah sangatlah diutamakan. Sekam padi merupakan antara bahan buangan utama daripada sektor pertanian di Malaysia dan kaedah pelupusannya iaitu secara pembakaran terbuka telah menyumbang kepada berlakunya pencemaran udara. Kecenderungan untuk mencampurkan sekam padi dengan simen dalam penstabilan tanah lembut mungkin merupakan jalan penyelesaian terhadap kedua-dua masalah tersebut. Matlamat kajian ini adalah untuk mengkaji kegunaan simen-sekam padi sebagai bahan penstabil tanah yang berkesan dalam memperbaiki ciri-ciri mekanikal tanah liat. Ujikaji-ujikaji makmal dijalankan terhadap tanah liat terstabil untuk mengkaji hubungan antara halaju gelombang ricih, pemampatan satu dimensi dan kekuatan mampatan tak terkurung. Sampel tanah liat diambil dari Pusat Penyelidikan Tanah Lembut (RECESS), UTHM. Spesimen yang terstabil disediakan dengan mencampurkan tanah liat dengan 5 % dan 10 % simen dan pelbagai kuantiti sekam padi. Kemudiannya, dimampatkan menjadi spesimen silinder berukuran 38 mm dan ketinggian 76 mm. Spesimen-spesimen tersebut kemudiannya diawet pada tempoh berlainan sehingga sebulan. Spesimen-spesimen tersebut dipantau bagi memastikan terdapatnya kenaikan nilai-nilai kekukuhan dan kekuatannya, serta penurunan mendapan yang efektif, yang menunjukkan terdapatnya potensi untuk simen-sekam padi sebagai bahan penstabil alternatif untuk tanah liat.

Kata kunci: *penstabilan tanah liat, simen, sekam padi, halaju gelombang ricih, pemampatan satu dimensi dan kekuatan mampatan tak terkurung.*

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LIST OF SYMBOLS AND ABBREVIATIONS

(τ)	-	time shift
A	-	cross section area
Al_2O_3	-	Alumina
BE	-	Bender element
C	-	cement
C_2S	-	Dicalcium silicate
C_2SH_x, $C_3S_2H_x$	-	hydrated calcium silicates
C_3A	-	Tricalcium aluminate
C_3AH_x, C_4AH_x	-	hydrated calcium aluminates
C_3S	-	Tricalcium silicate
C_4AF	-	Tetracalcium alumino-ferrite
$Ca(OH)_2$	-	hydrated lime
Ca^{2+}	-	Calcium ion
CaO	-	Calcium Oxide
$CC_{xy}(t)$,	-	cross-correlation function
CO_2	-	Carbon dioxide
C-S-H	-	calcium silicate hydrate
c_u	-	undrained shear strength

c_v	-	coefficient of consolidation
DMM	-	Deep Mixing Method
DSM	-	deep soil mixing
e	-	void ratio
e.g.	-	for example
E_{50}	-	secant modulus at 50 % of peak stress
E_o	-	initial tangent modulus
E_p	-	peak stress
f	-	frequency of the transmitted signal
Fe_2O_3	-	Iron Oxide
G_s	-	Specific gravity
G_o	-	Maximum shear modulus
i.e.	-	in other words
K^+	-	Potassium ion
K_2O	-	Potassium Oxide
kHz	-	kilohertz
L	-	effective distance traveled by the shear wave through the soil specimen
l	-	distance traveled
m	-	meter
Mg^{2+}	-	Magnesium Oxide

MgO	-	Magnesium Oxide
mm	-	milimeter
m_v	-	coefficient of volume compressibility
Na_2O	-	Sodium Oxide
NCL	-	normal consolidation line
NDT	-	Nondestructive test
OPC	-	Ordinary Portland cement
P	-	compressive force
P_c	-	preconsolidation pressure
POC	-	palm oil clinker
q_u	-	unconfined compressive strength
R^2	-	coefficient of correlation
RCff	-	column free-free tests
R_d	-	near field effect
RECESS	-	Research Centre for Soft Soils
RH	-	Rice husk
RHA	-	rice husk ash
RL	-	regression line
SASW	-	Spectral analysis surface wave
SiO_2	-	Silica

SO_3	-	Sulphur Trioxide
SO_4^{2+}	-	Sulfate ion
t	-	tonne
t	-	travel time
TiO_2	-	Titanium Oxide
t_o	-	first time of arrival
t_{pp}	-	first peak to peak time
UCS	-	unconfined compressive strength test
UTHM	-	Universiti Tun Hussein Onn Malaysia
v	-	Poisson's ratio
v_s	-	shear wave velocity
w	-	moisture content
W_s	-	dry weight
W_w	-	wet weight
$X(T)$	-	degree of correlation of the received signal
XRF	-	X-ray Fluorescence
$Y(T)$	-	transmitted signal
μm	-	micro meter
ρ	-	density
σ_y'	-	yield stress

CHAPTER 1

INTRODUCTION

1.1 Research Background

At present, for various types of construction on soft soils, engineers are forced to lay foundation over the soft materials to avoid instability and excessive or non-uniform settlement problems. To this end, a variety of ground improvement techniques have been developed and put into practice so far.

The Deep Mixing Method (DMM), a deep in-situ soil stabilization technique using cement and lime as a stabilizing agent, was developed in Japan and the Scandinavian countries independently in 1970s. Numerous research efforts have been carried out in these areas to investigate properties of treated soil, behaviour of DMM improved ground under static and dynamic loading conditions, design methods as well as execution techniques (CDIT, 2002).

The purposes of stabilizing agent addition to soft soils can be stated briefly as follows:

- To increase the strength and stiffness of soft soil.
- To reduce excessive and differential deformations of the soft soil.
- To increase dynamic stiffness of the soft soil.

EuroSoilStab (2002) listed the following advantages of deep stabilization compared to other stabilization methods (i.e. vertical drains and piling):

- Economic in terms of savings of material and energy.
- Flexibility in terms of improving engineering properties.
- It can be flexibly linked with other structures and with the surroundings (no harmful settlement differences).
- It has less impact on the environment with minimal spoil production.

There are many types of stabilizing agents that possess hardening properties and various studies have been published on the stabilization effects of these stabilizing agents. According to Sing et al. (2007), the important criterion in selection of suitable stabilizing agents is their capability of achieving the desirable soil stabilizing function. With appropriate choice of stabilizing agents, soil stabilization by suitable chemical admixture can increase shear strength and bearing capacity, reduce permeability and compressibility and improve swelling characteristics of soft soils.

In most agricultural-based countries, such as Indonesia, Malaysia, Philippines and Thailand, disposal of the abundant agriculture wastes is a pressing issue, especially from the perspective of sustainability and environmental preservation. According to Basha et al. (2005), as a result of the increase in the amount of solid waste all over the globe, engineers and researchers are obliged to carry out investigations to find useful applications for such wastes. The lower cost makes it an attractive alternative if adequate performance can be obtained.

In Malaysia, for instance, the proper disposal of rice husk (RH) has become a problem, especially when open burning is no longer permitted due to environmental concerns (Sarkawi and Aziz, 2003). The problems caused by irresponsible disposal of this agricultural waste can be significantly reduced by finding suitable engineering applications for its afterlife, such as being used as part of the lightweight backfill material in geotechnical projects.

In an effort to reuse the large quantities of RH, this study was carried out to examine the possibility of utilizing the waste material for soil stabilization. The effectiveness of unburnt RH in soil stabilization was determined by conducting the mechanical tests of stabilized clay with cement and RH.

One of the nondestructive test (NDT) methods is the shear wave velocity measurement with bender element (BE) test. According to Sahaphol and Miura (2004), BE test is a simple technique and is noted as effective tool to determine the maximum shear modulus (G_o) of soil by measuring the velocity of propagation of a shear wave through a soil specimen. This may be due to the simplicity of the test procedure and its non-destructive nature. The obvious advantage of using BE test is that the number of test specimens can be significantly reduced, where the same specimen can be repeatedly tested over a length of time at desired intervals, with minimal disturbance to the specimen itself.

The simultaneous measurement of shear wave velocity provides complementary microlevel information on the fundamental parameters of the physical changes and rigidity in stabilized specimen (Fam and Santamarina, 1996). Besides, the application of the results will assist in field monitoring and assessment of the quality of stabilized soils using seismic methods. Therefore this research focused on shear wave velocity measurements and the correlations of these measurements with other conventional tests for strength and compressibility that can be useful for design works on stabilized soils.

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